Calcite saturation indices of ground-water samples indicate a higher potential for karstic dissolution from late fall through early spring than in the summer. The relatively short residence time (5-7 hours) and rapid flow velocity (nearly 500 feet per hour) for lake water to leak into the aquifer and exit at the boil suggests that this water would not reach equilibrium while in transit.

H72C-0865 1330h INVITED POSTER

Sources and Chronology of Nitrate Contamination of Spring Waters: Integrating Science and Policy Decisions

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Human health and ecological concerns have arisen regarding spring waters in Florida as a steady increase in nitrate concentrations has been observed during the past 30 years. The extensive aesthetic, cultural, and recreational value of these springs, which also supply water for human consumption and support critical ecological habitats, could be threatened by the presence of nitrate. As part of the response to these concerns by the State of Florida, several research studies have used various chemical and isotopic tracers to determine sources of nitrate contamination and age of ground water discharging from springs. Since 1997, 60 water samples have been collected from 44 springs and analyzed for isotopic (^{15}N, $^{3}H/^{3}He$, ^{18}O, ^{2}H, ^{13}C) and other chemical tracers (CFCs, major ions, dissolved gases, SF_6). Delta ^{15}N values of nitrate ranged from 2.6 to 12.9 per mil (median = 5.8 per mil) and indicated that nitrate in most spring waters originated from synthetic fertilizers. CFCs, $^{3}H/^{3}He$, and SF_6, used to estimate the residence time of ground water discharging from springs, indicated that spring-water ages ranged from <1 to 39 years. Concentrations of these multiple tracers are consistent with a two-component hydrologic model with mixtures of varying proportions of young water (less than 8 years) from the shallow part of the aquifer system and older water (20-50 years) from the deeper part of the flow system. Given residence times of 20-40 years for ground water discharging from most springs, it could take decades for nitrate concentrations to decrease to near background levels, even with immediate reductions in nitrogen inputs to the land surface. These research results are being used by the State of Florida to inform elected officials, water-resource mangers, and planners that decisions about land use today will affect the quality of ground water in springs for decades.

H72C-0866 1330h POSTER

Nitrate Source, Transport and Fate in Ground Water Near La Pine, Oregon

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A shallow, sandy aquifer serves as both the source of drinking water and the receptor of septic tank effluent for most residents in the vicinity of La Pine, Oregon. High concentrations of NO_3^- (>10 mg NO_3^--N/L) first were observed in study area ground water in the early 1980s. A framework for understanding NO_3^- dynamics and a conceptual model in support of a numerical NO_3^- transport model are described here.

Geochemical and hydrogeologic data were collected at a variety of scales to develop an aquifer scale (640 km^2 area, 37-m thickness) understanding of NO_3^- source, advection, dispersion, and fate. A network of 61 existing wells, two transects of monitoring wells installed along ground-water flowpaths, a dense array of direct-push wells installed perpendicular to one of the transects, and three wells installed in septic tank effluent plumes were sampled and variously analyzed for common ions, nutrients, dissolved organic carbon, field parameters, dissolved gases, isotopes of water and nitrogen, and age-dating tracers (CFCs, ^{3}H, $^{3}H/^{3}He$).

Nitrogen isotopes, N/Cl^- relations, age gradients, and hydraulic considerations indicate that septic tank effluent is the dominant source of NO_3^- in the aquifer. Most NO_3^- currently resides within the upper 5 m of the aquifer, due in large part to low recharge rates (CFC-based ground-water age gradients indicate a median recharge rate of 5.1 cm/y) and low hydraulic gradients that limit advection. High concentrations of NH_4^+ (up to 39 mg NH_4^+-N/L) were observed in deep (generally > 37 m) ground water (water that, for the most part, resides beneath the primary aquifer). Nitrogen isotopes, N/Cl^- and N/C relations, ^{3}H data, and hydraulic considerations point to a natural, sedimentary organic matter source for this NH_4^+. Relations between NO_3^-, Cl^-, and geochemical indicators of redox conditions, and relations between concentrations and isotopes of N_2, indicate that denitrification is extensive in the study area. Denitrification occurs near the oxic/suboxic boundary. Laboratory denitrification experiments with aquifer sediments confirm the existence of a denitrification capacity in sediments currently exposed to NO_3^-, and also demonstrate a latent denitrification capacity in sediments collected from what is currently NO_3^--free ground water.

Our data allowed development of a framework and a conceptual model for the NO_3^- transport model. Septic tank effluent is the dominant NO_3^- source term; census data were combined with study area septic tank effluent data to estimate NO_3^- loading terms. Concentration data from a dense array of wells facilitated estimation of dispersion. Advection of NO_3^- occurs until NO_3^- reaches the oxic/suboxic boundary, at which point denitrification quickly results in reduction of NO_3^- to N_2. Age-dating data were combined with hydraulic head, slug test, and ground-water/surface-water interactions data to constrain and calibrate the transport model. Results from the transport model are being presented by Morgan et al. in a separate Fall, 2002 AGU session.

H72C-0867 1330h POSTER

Isotopic Evidence for the Impact of Playa Water on Shallow Groundwater Flow in the Snake River Aquifer Beneath the INEEL

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The Idaho National Engineering and Environmental Laboratory (INEEL) is located on the Snake River Plain in eastern Idaho. At Test Area North (TAN) on the INEEL, waste consisting of low-level radioactive isotopes, sewage and chlorinated solvents was injected into the upper aquifer through a 95 m well, resulting in a 2 km plume of TCE in the groundwater. The geology consists of fractured basalt flows separated by sedimentary interbeds. The depth to groundwater at the site is 65 m. At 120-160 m depth, a continuous interbed (the Q-R) acts as a confining layer between the upper and lower aquifer. The primary direction of flow in the Snake River Aquifer is NE to SW, but flow at TAN (as defined by the TCE plume) is perpendicular to the regional flow, starting out to the east and bending to the SE. Possible causes of this anomalous flow include injection and/or infiltration of wastewater, infiltration of water from ephemeral playa lakes (dry for the last 50 years due to agricultural diversion), or heterogeneous permeability due to subsurface geological features. Understanding this flow is critical for determining the risk factors associated with the contamination.

We have measured the isotopic compositions of surface and groundwater from TAN. Water above the Q-R interbed is evaporated ($\delta^{18}O$ values shifted up to $3^o/_{oo}$). The degree of evaporation increases towards the edge of outline of the closest playa. The $^{87}Sr/^{86}Sr$ values are very uniform (0.71035±0.0001) and are equal to samples from the playa system. Conversely, water beneath the Q-R is not contaminated and is isotopically distinct from the water above the interbed (no evaporation, $^{87}Sr/^{86}Sr$ values >0.711). The playa water is the primary factor producing the flow patterns observed in the TAN area. Radiocarbon ages calculated from the ^{14}C of DIC are 1800 to 2800 years BP, giving infiltration rates of 2-3 cm/yr. Given the possibility of subsurface DIC exchange with carbonates, these ages should be considered minimum ages, however, they suggest that the playas will affect groundwater flow directions well into the future.

H72C-0868 1330h POSTER

Chemical and Isotopic Tracers of Groundwater Sustainability: an Overview of New Science Directions

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Groundwater sustainability is an emerging concept that is rapidly gaining attention from both scientists and water resource managers, particularly with regard to contamination and degradation of water quality in strategic aquifers. The sustainability of a groundwater resource is a complex function of its susceptibility to factors such as intrusion of poor-quality water from diverse sources, lack of sufficient recharge and reorganization of groundwater flowpaths in response to excessive abstraction. In theory the critical limit occurs when degradation becomes irreversible, such that remediative efforts may be fruitless on a reasonable human time scale. Chemical and isotopic tracers are proving to be especially useful tools for assessment of groundwater sustainability issues such as characterization of recharge, identification of potential sources, pathways and impacts of contaminants and prediction of how hydrology will change in response to excessive abstraction. A variety of relatively cost-efficient tracers are now available with which to assess the susceptibility of groundwater reserves to contamination from both natural and anthropogenic sources, and may provide valuable monitoring and regulatory tools for water resource managers. In this overview, the results of several ongoing groundwater studies by the U.S. Geological Survey will be discussed from the perspective of implications for new science directions for groundwater sustainability research that can benefit water policy development. A fundamental concept is that chemical and isotopic tracers used individually often provide ambiguous information, and are most effective when used in a rigorous "multi-tracer" context that considers the complex linkages between the hydrology, geology and biology of groundwater systems.

H72C-0869 1330h POSTER

Assessing Contaminant Susceptibility Near Artificial Recharge Operations by Imaging Flowpaths and Transport Times With Geochemical Tracers

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Critical for assessing the potential impacts of artificial recharge operations on water quality is detailed knowledge of groundwater dynamics near spreading areas. Geochemical tracer techniques including tritium/hellium-3 ($T/^{3}He$) dating and the addition of trace gases in controlled experiments are ideally suited for these investigations. A series of experiments were conducted using these tracers near the artificial recharge facilities in Northern Orange County, CA. Here, approximately 2.5×10^8 m^3 of surface water are recharged annually to the groundwater basin. $T/^{3}He$ ages show that most of the relatively shallow groundwater within 3 km of the recharge facilities have ages less than 4 years; further down gradient ages increase, reaching >20 years at distances more than about 6 km. Far from the spreading area in the confined portions of the aquifer there is little evidence for young groundwater (<50 years). Gas tracer experiments using sulfur hexafluoride and xenon isotopes were conducted from two spreading basins and the Santa Ana River. These tracers were followed in the groundwater for up to 4.5 years, allowing subsurface flow patterns and flow times to selected wells to be quantified. Results demonstrate that the mean horizontal flow velocity range between 0.4 and 2.9 km yr^{-1}. It is likely that the gas tracers were moving primarily through the most conductive layers and thus these velocities do not represent bulk flow within all layers. The leading edge of the tracer plume moved at velocities about twice as fast as the center of mass. The latter velocities are important when considering the potential transport of microbes and other "time sensitive" contaminants because they reflect the fastest paths in the aquifer. These velocities can not be easily determined with other methods showing the importance of geochemical methods for artificial recharge site evaluation.